



Research

The Validity of Electromyography and Patient Evaluation Measurement in Evaluating Late-term Satisfaction Level of Patients Undergone Carpal Tunnel Syndrome Decompression Surgery

Karpal Tünel Sendromu Dekompresyon Cerrahisi Geçiren Hastaların Geç Dönem Memnuniyet Düzeylerini Değerlendirmede Elektromiyografi ve Hasta Değerlendirme Ölçümünün Geçerliliği

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ABSTRACT

Objective: This study investigated whether electromyography (EMG) evaluation is helpful in the late phase after surgical treatment of carpal tunnel syndrome (CTS).

Methods: This retrospective study included 35 patients who underwent mini-open decompression therapy between 2008 and 2011 with CTS diagnosis. Patients were assessed electrophysiologically and clinically with Patient Evaluation Measurement (PEM) scoring and handgrip, palmar grip, lateral grip, and fingertip grip strength. Additionally, patients' clinical scores and strength values were compared with electrophysiologic values from preoperative and postoperative 4-year controls.

Results: According to the Padua classification, EMG data were classified before and after surgery. One patient had extreme grade, four patients had severe grade, 26 patients had moderate grade, and four had a mild grade before surgery. At the postoperative 4th year EMG follow-up, six patients were classified as minimal and 29 as negative. According to the PEM scale, the mean score before surgery was 58.77±7.89, and in the controls at the 4th year after surgery, the mean score was 13.48±4.01. The strength of the operated hand was significantly weaker than that of the contralateral healthy hand before surgery. However, in the controls at the 4th year after surgery, the strength of the operated hand was significantly increased compared with the preoperative period, and there was no significant difference from the contralateral hand.

Conclusion: Electrophysiological assessment (EMG) in the late phase after surgical treatment of CTS has positive parallels with clinical assessment and strength assessment. Therefore, we conclude that EMG helps follow late surgical outcomes.

Keywords: Carpal tunnel, EMG, PEM

ÖZ

Amaç: Bu çalışmada, karpal tünel sendromunun (KTS) cerrahi tedavisi sonrası geç dönemde elektromiyografi (EMG) değerlendirmesinin yararlı olup olmadığı araştırıldı.

Gereç ve Yöntem: Bu retrospektif çalışmaya 2008-2011 yılları arasında KTS tanısı ile mini açık dekompresyon tedavisi uygulanan 35 hasta dahil edildi. Hastalar hem elektrofizyolojik hem de klinik olarak Patient Evaluation Measurement (PEM) skorlaması ve el kavrama, palmar kavrama,

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lateral kavrama ve parmak ucu kavrama güçleri ile değerlendirildik. Ek olarak, hastaların klinik skorları ve güç değerleri, ameliyat öncesi ve ameliyat sonrası 4 yıllık kontrollerden elde edilen elektrofizyolojik değerlerle karşılaştırdık.

Bulgular: Padua sınıflamasına göre EMG verileri ameliyat öncesi ve sonrası olarak sınıflandırıldı. Ameliyat öncesi bir hasta ileri, dört hasta ağır, 26 hasta orta ve dört hasta hafif dereceli olarak sınıflandırıldı. Ameliyat sonrası 4. yıl EMG takibinde altı hasta minimal ve 29 hasta negatif olarak sınıflandırıldı. PEM ölçeğine göre ameliyat öncesi ortalama $58,77 \pm 7,89$, ameliyat sonrası 4. yılda kontrollerde ortalama puan $13,48 \pm 4,01$ olarak bulundu. Ameliyat edilen elin gücü, ameliyat öncesi karşı taraftaki sağlıklı elden önemli ölçüde daha zayıf olarak tespit ettik. Ancak ameliyat sonrası 4. yılda yapılan kontrollerde ameliyat edilen elin kuvvetinde ameliyat öncesi döneme göre anlamlı düzeyde artış olduğu ve karşı taraf sağlam elden anlamlı bir fark olmadığı tespit ettik.

Sonuç: KTS'nin cerrahi tedavisinden sonraki geç dönemde elektrofizyolojik değerlendirme (EMG), klinik değerlendirme ve kuvvet değerlendirmeleri ile pozitif yönde paralellik göstermektedir. EMG'nin geç dönem cerrahi sonuçlarının takibinde yardımcı olabilmektedir.

Anahtar Kelimeler: Karpal tünel, EMG, PEM

INTRODUCTION

Carpal tunnel syndrome (CTS) is considered the most common entrapment neuropathy of the median nerve at the level of the wrist region in working-age individuals (1,2). CTS (prevalence was 3-3.4% in men and 0.6-2.7% in women) (2-5). No test alone has sufficient sensitivity for CTS diagnosis. However, patient history, physical examination, and electromyography (EMG) play an essential roles in diagnosis and follow-up (4,5). Several studies have reported that the sensitivity of conventional tests ranges from 49% to 84%, with specificity around 95% (4-6). Various conservative treatment modalities are acceptable in mild-to-moderate cases.

In contrast, surgical decompression procedures are reserved for more severe cases with thenar muscle atrophy or after the failure of conservative treatment (3,4). EMG has been a good method to quantify the severity of median nerve entrapment and correlate closely with the degree of preoperative symptoms compared with physical examination (5). Clinical examination, patient assessment measurements, and EMG are used to evaluate early and long-term postoperative decompression outcomes. However, the literature search revealed few studies comparing symptom resolution and patient satisfaction (6,7).

Recent studies have shown different discrepancies between different methods of postoperative assessment based on complementary tests such as EMG or clinical grading systems in terms of clinical and functional diagnosis and postoperative short- and long-term follow-up CTS decompression surgery (8,9).

Although several studies have shown the close relationship between the clinical presentation of CTS and EMG manifestation outcomes (9,10), many other studies have shown earlier symptomatic clinical improvement than EMG improvement, especially in severe forms of the disease due to the late recovery process of the demyelination nature of the nerve sheath due to the persistent compression-induced ischemic effect on the nerve sheath, which may take several

months to return to normal patterns (10,11). Therefore, the degree of postoperative patient satisfaction is considered one of the most important criteria for measuring the success rate of CTS decompression surgery (12,13). Apart from being an invasive and expensive examination method, the validity of EMG for measuring postoperative patient satisfaction has been discussed in several recent studies (14,15).

Our study investigates the effectiveness of physical EMG examination and clinical grading systems in the long-term follow-up of patients undergoing CTS decompression surgery.

METHODS

All the patients were investigated after the Taksim Training and Research Hospital's approval of the Clinical Research Ethics Committee (decision no: 110, date: 16.10.2019). Informed consent was also obtained from the patients. We reviewed the records of eighty-eight patients diagnosed in our orthopedic and traumatology outpatient clinic between 2008 and 2011 CTS who underwent minimal approach CTS decompression surgery.

All patients with metabolic syndromes, rheumatologic diseases, recurrent CTS, pregnancies, and trauma-related diseases were excluded. Simultaneously, patients with no prominent history of medical illness or trauma were included in the study.

Of the eighty-eight patients, 35 were included in this study (7 male and 28 female). Out of the 35 patients, 14 were left-handed CTS (40%), while 21 were right-handed CTS (60%). The mean age was 51.75 ± 5.33 years, while the mean body mass index was 29.82 ± 4.23 . The mean time between the onset of symptoms and the time of surgery was 6.51 ± 2.06 months (Table 1).

Surgical Technique: All patients were operated on by a single experienced surgeon using the same technique. Under a pneumatic tourniquet, after the upper limb was properly stained and draped, a 3-4 cm longitudinal incision

Table 1. Demographic, clinical and examination data of the patients

Gender (F/M)	28/7
Age (years)	51.75±5.33
Side (R/L)	21/14
Symptom onset time (months)	6.51±2.06
Numbness	94.55%
Weakness	69.3%
Night pain	85.71%
Tinel test positivity	77.14%
Phalen test positivity	68.57%
BMI (kg/m ²)	29.82±4.23

F: Female, M: Male, R: Right, L: Left, BMI: Body mass index

was made over the volar crease. The transverse carpal ligament, which forms the roof of the carpal tunnel, was completely transected, and the superficial palmar fascia was loosened. Only the skin was closed with a nonabsorbable 4/0 suture. A fixation splint was not applied after surgery, but an elastic bandage was applied. After surgery, patients were allowed to use their hands. Two weeks after the operation, the skin sutures were removed.

EMG was performed by the same neurologist using the EMG device. The EMG values of all patients were obtained 2-6 ±3.6 days before the surgical procedure, while the late postoperative term (48±3 months) EMG was performed after the completion of surgical decompression.

The diagnosis CTS was made when a peak velocity of conduction of sensation of the median nerve slower than 41.25 m/s or a velocity of conduction slower than 34 m/s of a mixed nerve on the palmar side of the hand and the volar side of the distal forearm (8 cm) or distal motor latency (DML) of the abductor pollicis brevis muscle longer than 3.6 m/s were recorded (15). The EMG results obtained were graded accordingly using the clinical grading system developed by Padua et al. (10).

Hand grasp strength was measured using a Jamar Dynamometer. In contrast, the power of the digits was measured using the Pinchmetre. All measurements were taken thrice, and the mean values of the three measurements were calculated in kilograms (kg). These measurements were taken one day before surgery and four years after the time of surgery.

The same surgeon assessed Tinel and Phalen's tests for all patients (16,17).

Patient Evaluation Measurement (PEM) clinical grading system was used for clinical evaluation. Many scoring systems have been developed to evaluate patient satisfaction and functional outcomes after CTS surgery. Studies indicate that the PEM questionnaire is easily

applicable, easy to understand, and reliable compared to other evaluations in evaluating patient satisfaction and functional results in the application and outcome stages of the treatment of CTS (17).

Statistical Analysis

Normality control in statistical analysis was performed by the Shapiro-Wilk test, histogram, Q-Q plot, and boxplot diagrams. Preoperative and control comparisons of EMG, PEM, and grip strength variables were performed using Wilcoxon signed-ranks test. The significance threshold was taken as $p < 0.05$ and bidirectional. The correlation between EMG, PEM, and grip strengths was evaluated using the Spearman correlation test ($p < 0.01$). Analysis were performed using the NCSS 10 software (2015. Kaysville, Utah, USA).

RESULTS

The mean EMG value of DML was 5.09 ± 0.07 m/s in the preoperative period, while it was 3.83 ± 0.12 m/s in the postoperative period. Moreover, a significant statistical difference was found between the DML values in the preoperative and late postoperative periods with a p-value of 0.0023.

According to the Padua evaluation criteria, EMG values, the mean Compound Action Potential (CMAP) of preoperative EMG was 8.49 ± 0.56 m/s, while the mean of postoperative EMG was 20.00 ± 1.14 m/s. Moreover, a significant statistical difference was found between the CMAP values in the preoperative and late postoperative periods with a p-value of 0.0037. As a result, the mean CMAP of preoperative EMG was 8.49 ± 0.56 m/s, while the mean of postoperative EMG was 20.00 ± 1.14 m/s. Additionally, a significant statistical difference was found between the CMAP values in the preoperative and late postoperative periods with a p-value of 0.0037.

The mean sensory nerve conduction velocity (SNCV) was 35.60 ± 3.44 m/s preoperatively and 52.26 ± 3.46 m/s postoperatively. A significant statistical difference was found between SNCV values in the preoperative and late postoperative periods with a p-value of 0.0074.

The sensory nerve action potential (SNAP) preoperative EMG mean was 3.31 ± 0.43 m/s, while the postoperative mean was 13.28 ± 0.61 m/s. Additionally, a significant statistical difference was found between the SNAP values in the preoperative and late postoperative periods with a p-value of 0.0025 (Table 2).

One patient showed advanced CTS in the preoperative period, four patients showed severe CTS, twenty-six

patients showed moderate CTS, and four patients showed mild CTS. However, the postoperative Padua chart showed minimal residual symptoms of entrapment in six patients and complete resolution of symptoms in twenty-nine patients.

Using the PEM criteria and the hand functional status assessment, the preoperative mean score was 58.77 ± 7.89 , while four years after surgery, it was 13.48 ± 4.01 . A significant statistical difference was found between the two preoperative and late postoperative period scores with a p-value of <0.0001 (Table 2).

Tinel and Phalen’s tests were performed in all patients an average of 1.3 weeks before and four years after surgery. Tinel sign was positive in 23 patients, while Phalen test was positive in 31 patients before surgery. Whereas Tinel sign was positive in 4 patients and Phalen test was positive in 2 patients four years after surgery.

The preoperative mean values of handgrip force, Palmer flexion force, lateral deviation force, and distal phalanx flexion force were (34.05 ± 2.98 , 14.00 ± 1.47 , 9.92 ± 1.72 , and 9.54 ± 0.74 kg) respectively. However, the mean values four

years after surgery were (41.71 ± 3.25 , 16.00 ± 1.26 , 12.28 ± 1.63 , 12.28 ± 1.63 , and 10.04 ± 0.84 kg). Statistical significance was found in all groups with p values of (0.0001, 0.0035, 0.0072, and 0.0022, respectively) (Table 3).

DISCUSSION

There is no standard evaluation algorithm to quantify the success rate in the postoperative period in carpal tunnel surgery (18,19). However, objective evaluation methods such as EMG and handgrip strength measurement and sometimes subjective evaluation methods such as physical examination and satisfaction measurement questionnaires can be used to assess decompression surgery’s success or failure rate (20,21).

EMG is considered highly sensitive in the diagnosis of CTS (22). The literature search revealed that many authors prefer EMG examination and physical examination to confirm the diagnosis of CTS. However, the role of EMG in the postoperative period to assess complete recovery and recurrence is still controversial (23).

Table 2. Comparison of EMG measurements before and after surgery

Variable	Preoperative	Postoperative control
Distal motor latency (ms)	5.09 ± 0.07	3.83 ± 0.12
Compound muscle action potential (ms)	8.49 ± 0.56	20.00 ± 1.14
Sensory nerve conduction velocity (ms)	35.60 ± 3.44	52.26 ± 3.46
Sensory nerve action potential (ms)	3.31 ± 0.43	13.28 ± 0.61

EMG: Electromyelography

Table 3. Comparison of handgrip strength, palmar grip, finger lateral grip, fingertip grip strengths preoperatively, postoperatively, and contralateral side

		Preoperative	4 th year control	p-value
Grip strength (kg)	Operated hand	34.05 ± 2.98	41.71 ± 3.25	<0.0001
	Contralateral hand	44.08 ± 2.99	42.77 ± 2.65	0.0858
	p-value	<0.0001	0.1008	-
Palmar grip (kg)	Operated hand	14.00 ± 1.47	16.00 ± 1.26	<0.0001
	Healthy hand	16.51 ± 1.31	16.62 ± 1.47	0.7281
	p-value	<0.0001	0.1293	-
Finger lateral grip (kg)	Operated hand	9.02 ± 1.72	12.28 ± 1.63	<0.0001
	Healthy hand	13.54 ± 1.54	13.05 ± 1.57	0.2076
	p-value	<0.0001	0.0620	-
Fingertip grip (kg)	Operated hand	9.54 ± 0.74	10.04 ± 0.84	<0.0001
	Healthy hand	10.85 ± 0.97	10.88 ± 1.49	0.9576
	p-value	<0.0001	0.1207	-

Yilmaz et al. (14) Compared EMG results and clinical manifestations of postoperative early CTS decompression surgery. He concluded that clinical healing was faster than EMG healing in the postoperative healing period; therefore, clinical presentation and EMG do not correlate closely, especially in the first three months after surgery (14).

EMG can help detail the syndrome with various differential diagnoses and recurrent cases, but in the classic CTS, ultrasound and magnetic resonance imaging are more useful noninvasive diagnostic measures (22,23).

Uchiyama et al. (15) have demonstrated that improvement in postoperative EMG values is slow and sometimes requires several months to show statistical significance compared with preoperative EMG values.

Louie et al. (16) showed that clinical improvement of patients after CTS decompression surgery improves much faster than EMG results within the first three months. In contrast, after 3-6 months, clinical improvement and EMG results correlate closely. However, six months after surgery, the trends had not evolved in favor of either assessment method (16).

EMG plays an essential role in diagnosing neural ischemia when an entrapped nerve is subjected to prolonged compression; even decompression surgery does not immediately recover neural ischemia, leading to long-term improvement in EMG scores (23,24).

In this study, the long-term results (after four years) of CTS decompression surgery evaluated by EMG improved significantly. Moreover, similar results were shown between the parameters of clinical evaluation variation and EMG results.

However, the improvement in late EMG results is mainly related to the nerve sheath's prolonged compression-induced neural ischemia effect.

This study showed similar results regarding handgrip strength weakness in patients with CTS. Patients diagnosed with moderate to severe CTS-developed weakness in handgrip strength (14-16). However, it was improved that clinical assessment parameters may return to normal values similar to those of the nondiseased limb in the late follow-up periods.

Although various charts have been described to measure postoperative patient satisfaction, the PEM scoring system is a simple, effective, and trustworthy method to assess functional and satisfactory outcomes after CTS decompression surgery (24,25).

This study evaluated functional outcomes and satisfaction levels before and four years after CTS decompression surgery. The PEM scoring technique, physical examination,

and EMG study showed similar and correlating results four years after CTS decompression surgery.

The different ages of patients, different gender, and different occupation are considered weak points in this study.

However, the use of the same surgical technique by the same surgeon, EMG, PEM, and clinical evaluation procedures assessed by the same neurologist are study strengths.

CONCLUSION

In late decompression surgery, the evaluation of CTS, PEM, hand measurements, and EMG has shown satisfactorily good and closely correlated results. Therefore, the PEM, hand measurements, and EMG may be reliable methods for evaluating the effects of CTS late decompression surgery.

ETHICS

Ethics Committee Approval: All the patients were investigated after the Taksim Training and Research Hospital's approval of the Clinical Research Ethics Committee (decision no: 110, date: 16.10.2019).

Informed Consent: Informed consent was also obtained from the patients.

Authorship Contributions

Surgical and Medical Practices: A.A., C.M., Concept: A.A., A.P., C.M., Design: A.A., M.Ü.Ç., A.K., N.A., Data Collection or Processing: M.Ü.Ç., A.K., Analysis or Interpretation: A.P., N.A., Literature Search: A.A., A.K., C.M., Writing: A.A., M.Ü.Ç., A.P., N.A.

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REFERENCES

- Ozcelik IB, Cift H, Ozkan K, Erturer E, Ugutmen E. Results of carpal tunnel decompression operations with minimal incision under regional anesthesia of the wrist. *Medeniyet Med J* 2011;26:10-3.
- Mottaghi M, Zare M, Pahlavanhosseini H, Mottaghi M. Carpal Tunnel Release Surgery Plus Intraoperative Corticosteroid Injection versus Carpal Tunnel Release Surgery Alone: A Double Blinded Clinical Trial. *J Hand Surg Asian Pac Vol* 2019;24:371-7.
- Giersiepen K, Spallek M. Carpal tunnel syndrome as an occupational disease. *Dtsch Arztebl Int* 2011;108:238-42.
- Park JW, Lee S, Jang RW, Lee S, Lee S, Cho H, et al. Optimal Ultrasonographic Measurements for Diagnosing Carpal Tunnel Syndrome in Patients With Diabetic Sensorimotor Polyneuropathy: A Case-Control Study. *Ann Rehabil Med* 2019;43:45-53.
- Ceceli E, Gumruk S, Okumus M, Kocaoglu S, Goksu H, Karagöz A. Comparison of 2 methods of neuropathic pain assessment in carpal tunnel syndrome and hand functions. *Neurosciences (Riyadh)* 2018;23:23-8.

6. Keniş-Coşkun Ö, Karadağ-Saygı E, Özsoy T, Giray E, Mansız-Kaplan B, Kora K. Does electrodiagnostic evidence correlate with mood and function in patients with a pre-diagnosis of carpal tunnel syndrome? *Turk J Phys Med Rehabil* 2017;63:335-9.
7. Faour-Martín O, Martín-Ferrero MA, Almaraz-Gómez A, Vega-Castrillo A. The long-term post-operative electromyographic evaluation of patients who have undergone carpal tunnel decompression. *J Bone Joint Surg Br* 2012;94:941-5.
8. Levine DW, Simmons BP, Koris MJ, Daltroy LH, Hohl GG, Fossel AH, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *J Bone Joint Surg Am* 1993;75:1585-92.
9. Izadi S, Kardeh B, Hooshiar SSH, Neydavoodi M, Borhani-Haghighi A. Correlation of clinical grading, physical tests and nerve conduction study in carpal tunnel syndrome. *Scand J Pain* 2018;18:345-50.
10. Padua L, LoMonaco M, Gregori B, Valente EM, Padua R, Tonali P. Neurophysiological classification and sensitivity in 500 carpal tunnel syndrome hands. *Acta Neurol Scand* 1997;96:211-7.
11. Sambandam SN, Priyanka P, Gul A, Ilango B. Critical analysis of outcome measures used in the assessment of carpal tunnel syndrome. *Int Orthop* 2008;32:497-504.
12. Heybeli N , Ozerdemoglu R , Aksoy O , Mumcu E . Functional and symptomatic scoring used for the assessment of outcome in carpal tunnel release. *Acta Orthop Traumatol Turc* 2001;35:147-51.
13. Bal E, Pişkin A, Ada S, Ademoğlu Y, Toros T, Kayalar M. Comparison between two mini incision techniques utilized in carpal tunnel release. *Acta Orthop Traumatol Turc* 2008;42:234-7.
14. Yilmaz N, Akdemir G, Gezici AR, Basmacı M, Ergungor MF, Asalanturk Y, Beskonakli E, Ucar D. Electrophysiological and clinical assessment of response to surgery in carpal tunnel. *Int J Neurosci* 2010;120:261-4.
15. Uchiyama S, Toriumi H, Nakagawa H, Kamimura M, Ishigaki N, Miyasaka T. Postoperative nerve conduction changes after open and endoscopic carpal tunnel release. *Clin Neurophysiol* 2002;113:64-70.
16. Louie D, Earp B, Blazar P. Long-term outcomes of carpal tunnel release: a critical review of the literature. *Hand (N Y)* 2012;7:242-6.
17. Dias JJ, Rajan RA, Thompson JR. Which questionnaire is best? The reliability, validity and ease of use of the Patient Evaluation Measure, the Disabilities of the Arm, Shoulder and Hand and the Michigan Hand Outcome Measure. *J Hand Surg Eur Vol* 2008;33:9-17.
18. Padua L, Coraci D, Erra C, Pazzaglia C, Paolasso I, Loreti C, et al. Carpal tunnel syndrome: clinical features, diagnosis, and management. *Lancet Neurol* 2016;15:1273-84.
19. Campagna R, Pessis E, Feydy A, Guerini H, Le Viet D, Corlobé P, et al. MRI assessment of recurrent carpal tunnel syndrome after open surgical release of the median nerve. *AJR Am J Roentgenol* 2009;193:644-50.
20. Makepeace A, Davis WA, Bruce DG, Davis TM. Incidence and determinants of carpal tunnel decompression surgery in type 2 diabetes: the Fremantle Diabetes Study. *Diabetes Care* 2008;31:498-500.
21. Wiesler ER, Chloros GD, Cartwright MS, Smith BP, Rushing J, Walker FO. The use of diagnostic ultrasound in carpal tunnel syndrome. *J Hand Surg Am* 2006;31:726-32.
22. Eroğlu A, Sarı E, Topuz AK, Şimşek H, Pusat S. Recurrent carpal tunnel syndrome: Evaluation and treatment of the possible causes. *World J Clin Cases* 2018;6:365-72.
23. Wolny T, Saulicz E, Linek P, Shacklock M, Myśliwiec A. Efficacy of Manual Therapy Including Neurodynamic Techniques for the Treatment of Carpal Tunnel Syndrome: A Randomized Controlled Trial. *J Manipulative Physiol Ther* 2017;40:263-72.
24. Hara Y, Nishiura Y, Ochiai N, Murai S, Yamazaki M. The relationship between preoperative needle electromyography findings and muscle power restoration after surgery in severe carpal tunnel syndrome patients. *J Orthop Sci* 2017;22:430-3.
25. Kim JY, Yoon JS, Kim SJ, Won SJ, Jeong JS. Carpal tunnel syndrome: Clinical, electrophysiological, and ultrasonographic ratio after surgery. *Muscle Nerve* 2012;45:183-8.